Fish Diets and Benthic Invertebrates in the Estuary of the Somass River, Port Alberni, British Columbia

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FISH DIETS AND BENTHIC INVERTEBRATES IN THE ESTUARY OF THE SOMASS RIVER, PORT ALBERNI, BRITISH COLUMBIA

by

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ABSTRACT

Birtwell, I. K., M. Wood, and D. K. Gordon. 1984. Fish diets and benthic invertebrates in the estuary of the Somass River, Port Alberni, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1799: 49 p.

This report presents information on the distribution and abundance of benthic invertebrates at five sites in the intertidal and shallow subtidal zones of the Somass River estuary. The diet of nine species of fish was examined in relation to the presence of benthic invertebrate prey. The study was carried out between May and July, 1975.

The distribution and abundance of benthic invertebrates differed between sampling locations. On the western side of the estuary, at Hoik Island, and at an undisturbed marsh area, the greatest number of taxa were recorded. A trend of decreasing numbers of invertebrate taxa and numbers of organisms occurred from west to east, across the estuary. Lower numbers of invertebrate taxa and of individuals were recorded on the eastern shoreline adjacent to the Port Alberni pulpmill complex, and the most impoverished intertidal benthic community was at a site (11), within a wharf complex, which received wastewaters, especially from the pulpmill complex. Oligochaetes, nematodes and copepods predominated in benthic samples collected on the industrialized eastern shore. In addition to these organisms, amphipods were particularly abundant at the more western stations sampled; they were absent at site 11.

The diet of juvenile chinook (Oncorhynchus tshawytscha), chum (O. keta), sockeye (O. nerka) and coho (O. kisutch) salmon, rainbow trout (Salmo gairdneri), Pacific staghorn sculpin (Leptocottus armatus), starry flounder (Platichthys stellatus), threespine stickleback (Gasterosteus aculeatus) and shiner perch (Cymatogaster aggregata) was examined. In general, the diet of these fish tended to reflect the composition of benthic invertebrate communities at the site of capture. While competition for food was apparent among certain species, the availability of preferred food items may be of most importance. For example, juvenile chinook salmon consumed primarily amphipods on the western, less industrialized side of the estuary, despite the presence of oligochaetes in densities similar to or greater than those on the industrialized eastern shore. Their diet changed with proximity to the outfall of the Port Alberni pulpmill, and insects became the most significant component, and at site 11, the most degraded of the sampling sites, oligochaetes were the primary dietary constituents, followed by insects. Similar trends were found for most other species of fish.

It was concluded that the absence or low numbers of certain taxonomic groups of benthic invertebrates was related to proximity to the Somass River, the discharge of effluent from the Port Alberni pulpmill, and industrial and

urban development on the eastern shoreline of the estuary. In turn, the diet of juvenile fish rearing in the shallow estuarine intertidal areas differed among sampling sites, particularly in relation to changes in the composition of benthic invertebrate communities. In view of the previously documented restricted habitat available to fish (especially salmonids) in the Somass River estuary, a cautious approach to fisheries management, wastewater management and further industrial development is required in order to provide appropriate food resources and environmental quality for wild fish populations and those reared artificially.

Key Words: Somass River estuary, fish diets, benthic invertebrates, pulpmill effluent

RÉSUMÉ

Birtwell, I. K., M. Wood, and D. K. Gordon. 1984. Fish diets and benthic invertebrates in the estuary of the Somass River, Port Alberni, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1799: 49 p.

Le présent rapport donne des informations sur la distribution et l'abondance d'invertébrés benthiques à cinq emplacements dans la zone intertidale et la zone infralittorale peu profonde de l'estuaire de la rivière Somass. On a étudié le régime alimentaire de neuf espèces de poissons en rapport avec la présence d'invertébrés benthiques. L'étude a été réalisée entre mai et juillet 1975.

La distribution et l'abondance d'invertébrés benthiques différaient selon l'endroit d'échantillonnage. C'est du côté ouest de l'estuaire, à l'île Hoik, et dans une région marécageuse non touchée que l'on a enregistré le plus grand nombre de taxons. Le nombre de taxons d'invertébrés et d'organismes avait tendance à diminuer d'ouest en est d'un côté à l'autre de l'estuaire. On a enregistré un moins grand nombre de taxons d'invertébrés et d'individus sur la rive est adjacente au complexe industriel de pâtes et de papiers de Port Alberni et la communauté benthique intertidale la plus pauvre a été observée à l'emplacement II, à l'intérieur d'un complexe portuaire, qui recevait des eaux usées, particulièrement en provenance du complexe industriel de pâtes et papiers. Les oligochètes, les nématodes et les copépodes étaient les organismes les plus nombreux dans les échantillons benthiques recueillis sur la rive est industrialisée. Outre ces organismes, les amphipodes étaient particulièrement abondants aux stations échantillonées situées le plus à l'ouest; ils étaient absents à l'emplacement II.

On a étudié le régime alimentaire de jeunes saumons quinnats (Oncorhynchus tschawytscha), kétas (O. kéta), rouges (O. nerka), et cohos (O. kisutch), de truites arc-en-ciel (Salmo gairdneri), de chabots armés (Leptocottus armatus), de flets étoilés (Platichthys stellatus), d'épinoches à trois épines (Gasterosteus oculeatus) et de perches-menés (Cymatogaster aggregata). De façon générale, le régime alimentaire de ces poissons avait tendance à refléter la composition des communautés d'invertébrés benthiques à l'endroit de leur capture. Etant donné que la concurrence pour la nourriture était visible entre certaines espèces, il se peut que la disponibilité des proies favorites joue un rôle des plus importants. Par exemple, les jeunes saumons quinnats se nourrissaient surtout d'amphipodes du côté ouest de l'estuaire, le moins industrialisé, malgré la présence d'oligochètes dont les densités étaient semblables ou supérieures à celles observées du côté est industrialisé. Leur régime alimentaire changeait à mesure qu'on se rapprochait de l'émissaire de l'usine de pâtes et papiers de Port Alberni, les

insectes devenant alors l'élément le plus important; à l'emplacement II, le plus dégradé des points d'échantillonnage, les oligochètes étaient les principaux constituants du régime alimentaire, suivis des insects. Des tendances semblables ont été observées pour la plupart des autres espèces de poissons.

Les auteurs concluent que l'absence ou la faible densité de certains groupes d'invertébrés benthiques était liée à la proximité de la rivière Somass, où se déversent les effluents de l'usine de pâtes et papiers de Port Alberni, ainsi qu'au développement industriel et urbain sur la rive est de l'estuaire. Par ailleurs, le régime alimentaire des jeunes poissons grandissant dans les zones intertidales peu profondes de l'estuaire différait selon les points d'échantillonnage, particulièrement en fonction des changements dans la composition des communautés d'invertébrés benthiques. En raison de l'habitat restreint (étudié auparavant) que peuvent utiliser les poissons (particulièrement les salmonidés) dans l'estuaire de la rivière Somass, on doit aborder avec prudence les questions de la gestion des pêches, du traitement des eaux usées et du développement industriel afin de fournir aux populations de poissons sauvages et de poissons d'élevage des ressources alimentaires et des conditions environnementales appropriées.

Mots-clés: estuaire de la rivère Somass, régimes alimentaires des poissons, invertébrés benthiques, effluents d'usine de pâtes et papiers

INTRODUCTION

The Somass River drains into the headwaters of Alberni Inlet, which is situated on the west coast of Vancouver Island, British Columbia (Fig. 1). Urban and industrial development has occurred primarily on the eastern shore, thus encroaching upon the intertidal zone and estuarine waters. Most of the development has been associated with the forest products industry, in particular, the Port Alberni pulpmill. This mill discharges approximately 170 X 10^3 $m^3 \cdot d^{-1}$ (38 X 10^6 IGPD) of secondary treated effluent from aerated lagoons, into the freshwater layers of the highly stratified Somass River estuary. The effects which this discharge may have upon dissolved oxygen levels and phytoplankton communities in the estuary have been described by Parker and Sibert (1973) and Sibert and Parker (1973). Birtwell and Harbo (1980) and Birtwell et al. (1983a) deduced, from fish catch information and in-situ experimentation, that the deeper estuarine waters were underutilized by salmonids: a result of sub-optimal dissolved oxygen levels caused naturally and by the discharge of pulpmill effluent.

Biological information on the Somass River estuary is relatively sparse; a summary of that which was available up to 1980 has been compiled by Morris and Leaney (1980). Information on biological communities in this estuary prior to industrialization is not available, but a few recent investigations of invertebrate and fish communities have been reported in relation to pulpmill effluent (for example, Kask and Parker 1972, Harger et al. 1973a,b, Ketcham 1977, Birtwell 1978, Birtwell and Harbo 1980, Birtwell et al. 1983a,b)

This report supplies additional information on aquatic communities in the estuary. The occurrence, abundance and distribution of benthic communities is presented in relation to the diet of nine species of fish. A listing of the data generated by this study has been provided previously by Birtwell et al (1983b).

MATERIALS AND METHODS

BENTHIC INVERTEBRATES

Sediment samples were obtained using a plastic corer (3 cm x 7.5 cm in diameter), and immediately placed in 1 L plastic bottles containing 10% buffered formalin. Duplicate samples were taken from four tidal heights (defined as upper intertidal, mid intertidal, lower intertidal and subtidal) at five stations (Fig. 1), on a bi-weekly basis during June and July, 1975. Station 16 was located on the west side of Alberni harbour on the shore of Hoik Island, close to log storage areas, station 10 was adjacent to two small

islands in the tidal mud flat area (relatively undisturbed by industrial activity). Station 5 was situated in the freshwater marsh region close to the Somass River and station 4 at Lupsi Cupsi Point, next to the Port Alberni pulpmill complex. Station 11 was in the most highly developed area of the estuary, within the confines of a wharf. The upper intertidal stations were located at approximately 3.0 m, the mid intertidal sites at 1.5 m, and lower intertidal sites at 0 m, above chart datum respectively. Subtidal samples were collected between 1 and 2 m below the zero tide mark using a Shipek sediment sampler from which two cores were removed. These cores were of identical size to those taken in the intertidal area.

Samples were exposed to Rose Bengal for 24 hours prior to sorting. The samples were wet-sieved through a large mesh sieve to remove debris, then carefully sorted in an enamel tray before being retained by a 250 µm screen. A repeated decanting procedure was employed to ensure that all organisms had been obtained (as determined by scanning the remaining sediment under a dissecting microscope).

Large samples were divided using a plankton splitter, however in most cases, the entire sample was examined under a dissecting microscope. Organisms were identified and enumerated. Only whole organisms, or parts making up whole animals, were counted. In some cases, identification was facilitated by removing the Rose Bengal stain with 95% ethyl alcohol.

FISH DIET

Fish were captured by beach seine on a bi-weekly basis over a three month period which began in May 1975. Sampling was conducted over a two hour interval around high tides of 3.0 ± 0.4 m, at the same sites from which benthic invertebrate samples were obtained. The 30.5 x 1.8 m beach seine was deployed from a 6.3 m jet-driven boat. Fish that were captured and required for further study, were preserved in 10% buffered formalin and their stomachs removed later in the laboratory, where the number and types of prey items were determined.

RESULTS

The results presented here are a summary of the basic information that was gathered during this study and previously presented by Birtwell et al. (1983b) in a data report.

BENTHIC INVERTEBRATES

Table 1 is a taxonomic breakdown of the mean density of organisms (m^{-2}) at each sampling station; data from the four tidal zones were combined. Figure 2 reveals differences in the numbers of organisms between sites and how this varies when nematodes, foraminiferans and oligochaetes are excluded (to facilitate comparison with information gathered from fish diet investigations). Stations 16 and 10 were found to differ significantly from stations 5, 4 and 11 with respect to numbers of organisms. Progressing eastward from station 16 through to 11, the number of taxa per station decreased. This trend would also apply to the total number of organisms per station except for station 5 which had the lowest total.

Table 1 and Figures 3, 4 and 5 show that the presence and density of certain groups of organisms was highly dependent upon location in the estuary. Amphipods were most numerous at site 10 and none were found in samples collected at site 11. Corophium sp. were the most numerous amphipods. Oligochaetes were recorded at all stations sampled but were in highest densities at sites 10 and 4. Nematodes were also relatively more abundant at site 10 but numbers at site 4, close to the discharge of the pulpmill, were similar to those on the opposite side of the Somass River estuary, at site 16. The densities of copepods and isopods were also similar between sites 10 and 4. Insects were in greatest abundance at site 10, and gastropods were only recorded at this site. Ostracods were found in much greater densities at site 16 on the western part of the estuary and were not recorded at sites 4 and 11, close to the pulpmill. Polychaetes were also in relatively low numbers close to the pulpmill.

Tables 2a, b, c, and d present the mean density of benthic invertebrates (m^{-2}) at each station, and by tidal level. Figure 6 presents information on the relative densities of amphipods at each station and between tidal heights, while Figure 7 presents such information for insects and polychaetes, Figure 8 for copepods and isopods, and Figure 9 for nematodes and oligochaetes.

Upper intertidal zone

In the upper intertidal zone (Table 2a) stations 16 and 10 had the highest density of organisms and the greatest number of taxa. Stations 4 and 5 had lower densities of organisms, with those at station 11 being intermediate between densities at stations 4 and 5, and 16 and 10. The large numbers of oligochaetes and nematodes present at station 11 account for the greater organism density at this site relative to stations 4 and 5. Foraminiferans and harpacticoid copepods were absent from stations 4 and 5 while ostracods were absent from stations 4, 5 and 11. Gastropods (i.e. Littorina sp.) were only found at station 10 and amphipods were only found at stations 16 (Orchestia traskiana) and 5 (Corophium sp.).

Mid intertidal zone

In the mid intertidal zone (Table 2b) station 16 had the highest organism density, followed by stations 4 and 10 and then, at much lower values, stations 11 and 5. The high density at station 16 is almost completely due to the large numbers of foraminiferans; they were not found in samples collected from stations 10 and 4 and were only present in very small numbers at stations 5 and 11. As in the upper intertidal zone, amphipods were not collected from station 11 and gastropods (Littorina sp.) were only found at station 10. Isopods (i.e. Gnorimosphaeroma oregonensis) were absent from station 16 but they were found in extremely high numbers at station 10.

Excluding station 16, the number of taxa per station decreased from east to west.

Lower intertidal zone

The highest densities of organisms in the lower intertidal zone were found at stations 10 and 16 where amphipods, harpacticoid copepods, oligochaetes, nematodes and foraminiferans were the dominant groups (Table 2c). Densities at station 11 were the lowest. As in the mid intertidal zone, station 16 had a much larger number of formaminiferans than any of the other stations; these organisms were not recorded in samples collected from stations 10 and 5. Amphipods, insects and polychaetes were absent from station 11 in this zone. In addition, numbers of isopods (ie. G. oregonensis) at station 11 were low relative to the other stations. Ostracods were absent from stations 4, 5, and 11. The number of taxa at station 11 was half to one-third that recorded for the other sampling sites, and there was a trend of decreasing numbers west to east, across the estuary.

Subtidal zone

The total number of organisms (m^{-2}) at all subtidal zone stations (station 11 was not sampled in this zone) were similar, however station 10 was found to have a slightly higher density of organisms. The number of taxa per station was similar at all stations. Numbers of foraminiferans at station 16 were very low in this zone relative to their numbers at this station in the higher intertidal zones. Foraminiferans were also present at station 5 and absent from stations 10 and 4. Station 10 had a large number of amphipods relative to the other stations. Numbers of polychaetes and harpacticoid copepods were much higher at stations 16 and 10 than at stations 4 and 5. Conversely, densities of oligochaetes were much higher at stations 4 and 5 than at stations 16 and 10.

FISH DIET

Chinook salmon (Oncorhynchus tshawytscha)

Juvenile chinook salmon (Table 3a; Fig. 10) captured at stations 16 and 10 fed primarily on amphipods; insects were the second most abundant item in their food. Conversely, at stations 5 and 4 insects were eaten in the greatest numbers followed by amphipods. Oligochaetes were the most prevalent organisms in the food of chinook captured from station 11, and insects the next most abundant prey. Low numbers of isopods were found in the stomachs of chinook from all stations, and similarly a small number of mysids were in the diet of these fish from all stations except 11. In general, a wide variety of taxa was eaten at each station.

Chum salmon (O. keta)

Juvenile chum salmon were captured at all five sampling sites. Their main prey at stations 16 and 10 were insects, followed by amphipods (Table 3b). At station 5 harpacticoid copepods and amphipods were the first and second most abundant dietary constituents respectively. Large numbers of insects were also consumed. The diet of chum salmon taken at site 4 differed from that of chum salmon taken at other sites in that oligochaetes were the primary food, followed by insects and amphipods. At station 11, insects were the major prey of these fish.

Sockeye salmon (O. nerka)

The mean total number of prey items per stomach of juvenile sockeye salmon (Table 3c) was found to be much lower at all stations than that determined for the other juvenile salmon captured during this survey. In addition, there was a correspondingly high proportion of fish with empty stomachs or with stomachs containing digested contents. For example, at site 11 all of the five fish examined had only well digested stomach contents. This implies that feeding had not occurred close to the time of capture. At station 16, insects were the major food item followed by amphipods. At station 10, harpacticoid copepods, amphipods and insects were all consumed with about equal frequency. At station 5, insects were the only item eaten, while at site 4, insects and oligochaetes were the main prey.

Coho salmon (O. kisutch)

Juvenile coho salmon were not captured at station 11. At station 16 the diet of juvenile coho salmon was entirely of insects, but at stations 10 and 5 amphipods were the dominant food items with much fewer numbers of isopods and insects being eaten (Table 3d). Amphipods were also the most numerous prey type consumed at station 4; insects and polychaetes were relatively minor dietary constituents (Table 3d).

Rainbow trout (Salmo gairdneri)

Juvenile rainbow trout also were not captured at station 11. An examination of the prey of these fish from stations 16 and 10 revealed that harpacticoids were the most numerous food items eaten; amphipods were consumed in lesser numbers (Table 3e). Amphipods were, however, the most numerous prey taken at station 5 and especially so at station 4; nematodes and harpacticoids were the secondary dietary items at stations 5 and 4 respectively.

Pacific staghorn sculpin (Leptocottus armatus)

Contrasting with the catch of salmon, there was a much larger catch of Pacific staghorn sculpins from station 11 (unpublished information). Analysis of their diet showed that amphipods were consumed in the greatest numbers (Table 3f; Fig. 11). They were eaten at all sites except site 11, where insects were the primary prey. Oligochaetes were only eaten at site 11. Isopods were the secondary food item at station 5. At station 16, isopods and "eggs" were of secondary importance (numerically) in their diet. At station 11, isopods and calanoid copepods were the secondary prey types.

Starry Flounder (Platichthys stellatus)

Starry flounder were caught at all stations except station 5. The composition of their diets is presented in Table 3g. Amphipods, followed by isopods, were the main prey taken by these fish at station 16, 10 and 4. Large numbers of insects were also consumed by starry flounders collected from station 4. The primary prey items at station 11 were oligochaetes, and calanoid copepods were consumed in fewer numbers. Oligochaetes were not eaten at sites 16, 10 or 4.

Threespine stickleback (Gasterosteus aculeatus)

Insects were found to be the primary food items of threespine sticklebacks at all stations except station 16 (Table 3h). At station 16, calanoid copepods were the major food items and amphipods were consumed in fewer numbers. The secondary food items differed at each of the other stations. At station 10 they were amphipods and mysids, at station 5, "eggs", and at station 4 they were oligochaetes. At station 11 no one prey type was ranked as secondary for a wide range of taxa were taken in small numbers (Table 3h; Fig. 12).

Shiner perch (Cymatogaster aggregata)

Insects were found to be the most abundant prey in the stomachs of shiner perch at station 4 (Table 3i). Isopods were consumed in the highest numbers at station 16 while isopods and mysids ranked equally as the most frequently eaten items at station 10. No fish were collected from stations 5 and 11 for stomach contents analysis.

DISCUSSION

BENTHIC INVERTEBRATES

The benthic invertebrate community in shoreline areas of the Somass River estuary was found to be typified by large numbers of foraminiferans, nematodes and oligochaetes, moderate numbers of amphipods and harpacticoid copepods and rarer occurrences of other taxa. Ketcham (1977) and Harger et al. (1973a,b), suggested that the low benthic species diversity of this area, is related to the discharge of effluent from the Port Alberni pulpmill and the influx of Somass River water into the highly stratified estuary.

Harger et al. (1973a,b), found that benthic invertebrates in the upper and mid intertidal zones were most influenced by low salinities, whereas low levels of dissolved oxygen were considered to affect the benthic fauna of the lower intertidal and subtidal zones. Using 'colonization plates' held at various sites in the Somass River estuary and at a control site in Uchucklesit Inlet (off Alberni Inlet), Harger et al. (1973a) determined that the Port Alberni harbour area had an impoverished benthic (periphytic) fauna. The possible toxic effects of pulpmill effluent upon larval stages and a reduction in light transmission due to effluent residing above the halocline and thereby affecting phytoplankton growth and food for herbivores, were considered to be the main factors responsible for the findings. Ketcham (1977) also deduced that effluent from the pulpmill adversely influenced benthic communities along the eastern shoreline and especially within 2 km of the outfall.

The results of the above-mentioned studies relate to the dispersion of pulpmill effluent in the estuary. Werner and Hyslop (1967) found that effluent tended to be more concentrated along the eastern shoreline. Similar findings were obtained by Birtwell (1978) who used colour values to trace effluent in the intertidal zone of the estuary. Stations 11 and 4, closest to the outfall of the Port Alberni pulpmill had the highest colour values (equated to effluent concentrations), and differed significantly from sites 5, 10 and 11 (values at these site tended to reflect their distance from the outfall). In addition, conductivity values differed significantly among sampling sites. Site 5, closest to the Somass River, had the lowest values, while those recorded at sites 16 and 11, on opposite sides of the estuary, had the highest conductivity levels. Temperature values were not significantly different among sampling sites.

As mentioned by Harger et al. (1973a,b) the marked stratification of the Somass River estuary most probably has a profound effect on the benthic intertidal communities at the head of Alberni Inlet. Birtwell (1978) and Birtwell et al. (1983a) described features of this stratification during spring and early summer. Waters below the halocline (i.e. below about 2-4 m depth) were characterized by lower temperatures, higher salinities and lower dissolved oxygen levels (1.5 - 5 $mg \cdot L^{-1}$), than waters above this zone. Tidal action would subject intertidal communities to a wide range of environmental variables due to this marked vertical stratification, and, accordingly, responses in the benthic communities would be expected.

While the identification and separation of factors associated with variations in benthic communities is not possible, there are some trends that tend to support the findings of previous studies in the area (e.g. by Harger et al. 1973a,b; Ketcham 1977).

In our study, differences in the density of organisms and species composition varied among the five sampling sites in the Somass River estuary. Stations 16 and 10, on the western and less industrialized side, had significantly higher densities of organisms and greater species diversities than those recorded at sites 5, 4 and 11. In addition, groups such as calanoid copepods, tanaidaceans, gastropods, ostracods and foraminiferans were absent, or, as in the case of the latter two, only present in greatly reduced numbers at sites 5, 4 and 11 on the eastern part of the estuary. Taxonomic diversity also decreased west to east across the estuary, that is, with progression towards the Somass River and the more industrialized areas.

Comparison of effluent distribution and benthic fauna data reveals that in areas of high effluent concentrations along the eastern shoreline (stations 4 and 11) species diversity and population density values were low. Thus, it appears that the presence and abundance of certain taxonomic groups was related, in part, to the distribution of pulpmill effluent within the estuary and proximity to the Somass River.

FISH DIET

Based upon the broad assumption that fish captured at a particular location had been feeding in the general vicinity of that site, it is apparent that the diet of some species of fish reflected the availability of certain prey. Table 4 summarizes the primary and secondary prey taken by the nine species of fish that were examined. This summary is based only upon the numbers of dietary constituents consumed and, accordingly, may not appropriately represent the importance of particular prey to the fish. Nevertheless, the results reveal that relatively few prey categories were consumed by the fish, and that, at least for some species, competition for food resources may have occurred in the estuary.

Chinook salmon (O. tshawytscha)

Juvenile chinook salmon have been found to consume a wide variety of prey, but in the lower reaches of the Fraser River and estuary, the smaller fish (<50 mm) were found to feed mainly upon insects, whereas for larger fish crustaceans and fish were dominant prey items (Northcote et al. 1979). Recent investigations in the estuary of the Campbell River (Macdonald and Levings, in press) revealed that insects, copepods and amphipods were common prey items for both hatchery and "wild" juvenile chinook salmon. However, wild chinook consumed larger numbers of insects and harpacticoid copepods than did hatchery fish. A greater proportion of hatchery fish were also found to have empty stomachs (27% to 5%, hatchery to wild chinook, respectively), and hatchery fish were the only fish to consume 'non-food' items such as wood and 'rocks'.

In Alberni Inlet, studies by Kask and Parker (1972) revealed that juvenile chinook in nearshore areas, but over deep waters, fed upon mud-dwelling cumaceans, copepods and cladocerans. In more open waters, chinook were found to feed upon a variety of marine organisms, and presumably would have penetrated below, or to, the halocline to take such prey. In shoreline areas our results reveal a significant shift in the diet of juvenile chinook between sites on the western side of the estuary and the eastern industrialized side; a shift that was reflected, primarily, by a change in the composition of benthic intertidal invertebrates. Amphipods were the primary prey on the western side of the estuary, and the diet changed markedly with proximity to the Port Alberni pulpmill, as did the composition of benthic invertebrates. At site 11, the most impoverished site for benthic invertebrates, oligochaetes were the primary food item taken, followed by insects. Amphipods were not recorded at this site. It is probable that the dependence of chinook salmon on oligochaetes at site 11 reflected the absence of other, possibly more preferable, food items such as amphipods. Tokar (1968) found that the consumption of oligochaetes which had been immersed in 100% KME reduced the growth of juvenile chinook salmon. However, analysis of the length, weight and condition factor of juvenile chinook between sites in the Somass River estuary did not reveal such an impairment (Birtwell 1978). The analysis undertaken did not, however, separate hatchery from "wild" chinooks and differential growth rates may well have occurred in relation to different residence periods and water quality conditions in the estuary (Birtwell, unpublished information). These observations on the diet of chinook salmon reveal that these fish are quite resourceful. They did not avoid areas which had a paucity or absence of 'preferred' food items. Furthermore, the relationship between benthic invertebrate data and the results of stomach content analyses are sufficiently strong, when associated with mark-recapture information (Birtwell, unpublished information), to suggest that juvenile chinook salmon occupied particular habitats for protracted periods during their residence in the Somass River estuary.

Chum salmon (*O. keta*)

Relatively few stomachs of juvenile chum salmon were analyzed, and conclusions are difficult to derive because of this. Although there was a shift in the composition of their diet between sites in the estuary, it was not as marked as that for chinook salmon, and a wider variety of organisms comprised the primary and secondary prey. In the Fraser River estuary, Northcote et al.(1979) found that crustaceans and insects were the main prey. Typically the diet of this species comprises a high proportion of harpacticoid copepods in estuarine and marine environments (e.g. Sibert et al. 1977, regarding the Nanaimo River estuary; Macdonald and Levings, in press, in relation to the Campbell River estuary). In the estuary of the Somass River, harpacticoid copepods were most numerous in the diet of chum salmon collected at site 5, close to the Somass River, and insects, amphipods and oligochaetes were other important prey items, despite the presence of harpacticoid copepods at all sampling sites.

Sockeye salmon (O. nerka)

Juvenile sockeye salmon had a relatively high proportion of empty stomachs, and all fish captured at site 11 on the eastern shoreline had a small amount of unidentifiable digested food in their stomachs. In the estuary of the Fraser River, in Tilbury and Deas Sloughs, copepods and cladocerans were primary prey (D.F.O. unpublished information) whereas insects were a major portion of the diet of juvenile sockeye salmon in the mainstem Fraser River (Northcote et al. 1979). The seemingly low feeding success of sockeye salmon in the estuary of the Somass River or their apparent lack of recent feeding, e.g. at site 11, is not readily explained. Similar to the diet of chum salmon, oligochaetes were consumed at site 4 close to the Port Alberni pulpmill.

Coho salmon (O. kisutch)

Very few juvenile coho salmon stomachs (14) were examined, however, it is apparent that amphipods and insects were the predominant prey, as they were for chinook and to a lesser extent, chum salmon. No juvenile coho salmon were captured at site 11, on the eastern shoreline.

Rainbow trout (S. gairdneri)

As for coho salmon, no juvenile rainbow trout were captured at the most severely degraded sampling site (11) on the eastern shoreline. Very few stomachs from rainbow trout were analyzed, but amphipods and copepods were found to be the main dietary constituents.

Pacific staghorn sculpin (L. armatus)

In the estuary of the Fraser River, Northcote et al. (1979) found that mysids, amphipods and isopods were the predominant prey items. A similar diet was found in those Pacific staghorn sculpins collected from the Somass River estuary. However, a shift in their diet was apparent between the western and eastern parts of the estuary. Whereas amphipods were the major dietary constituents at most sites, at site 11 insects were the dominant prey. Here, the scarcity or absence of amphipods, as determined through benthic invertebrate sampling, may well reflect the availability of these prey, and, as for chum salmon and to a lesser extent chinook salmon, insects were consumed.

Starry flounder (P. stellatus)

Very few samples of this species were obtained, but there is evidence of a shift in their diet within the estuary. On the western shoreline, mid estuary, and the site closest to the pulpmill, amphipods and isopods predominated in the diet, but at site 11, oligochaetes were the primary prey, as they were for chinook salmon captured at this site. Similarly Northcote et al.(1979) recorded that oligochaetes, small crustaceans and insects were their main prey in the Fraser River estuary.

Threespine stickleback (G. aculeatus)

Insects were the major components in the diet of these fish, and a relatively wide diversity of prey types was consumed. In the Fraser River estuary, Northcote et al. (1979) also found that small crustaceans were an important component of the diet, but that insects were more prevalent in threespine sticklebacks taken from the mainstem river sections. Oligochaetes were only consumed in moderate numbers at the eastern shoreline sampling sites in the estuary of the Somass River. Similarly oligochaetes were eaten by threespine sticklebacks in the estuary of the Fraser River, but they comprised an extremely small fraction of their diet.

Shiner perch (C. aggregata)

Only 54 stomachs of this fish species were examined, and, accordingly, it is difficult to determine changes in dietary components among stations. At site 5 (Somass River) and site 11 the two fish captured at each site had empty stomachs. At site 4, closest to the pulpmill, insects were the major dietary component, as for threespine stickleback, sockeye and chinook salmon.

CONCLUSIONS

It is apparent that the benthic nearshore and intertidal invertebrate communities feature in the diet of juvenile fish in the Somass River estuary. Changes in the abundance and distribution of benthic invertebrates were reflected in the diet of fish, thus indicating the flexibility of certain species to adjust their feeding habits. The changes also appear to be influenced by proximity to the Somass River and the effluent from the Port Alberni pulpmill. Major changes occurred in the diet of certain fish in the more polluted regions, and also in benthic communities along the industrialized eastern shoreline. Overall, we concluded that amphipods and insects were the two major prey groups for juvenile fish in the intertidal area. While this may reflect a certain degree of competition for food between species, perhaps of more importance is the change in availability of prey between areas in the estuary. With increased production of salmonids in the Somass River system, greater competition for food may be expected. Naturally produced (wild) chinook salmon rear in the Somass estuary for extended periods of time, in contrast to hatchery-produced chinook which tend to reside for a shorter period (Birtwell 1978). Perhaps unlike relatively unpolluted estuaries, such as that of the Campbell River, where hatchery chinook can effectively exploit food resources below the halocline or in surface marine waters (Macdonald and Levings, in press), chinook in the Somass estuary are severely limited in their vertical movements due to adverse dissolved oxygen conditions in marine waters at depth (Birtwell 1978; Birtwell et al. 1983a). Because of this, competition between wild fish and hatchery-reared chinook may

be increased for certain periods in the spring and early summer. Since this work was carried out in 1975, the hatchery production of chinook salmon alone, to the Somass River system, has increased substantially (1.7 million, 1975; 9 million, 1984), and competition may well have increased correspondingly. Accordingly, it will be necessary to safeguard against further changes to the Somass River estuary due to, for example, the discharge of pollutants, and industrial and urban development. In addition, it is essential to more fully understand the requirements of 'wild' populations of fish (particularly, chinook salmon), and their interaction with those reared artifically.

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Table 1. Mean number of organisms (m^{-2}) at five sampling sites (tidal zones combined), in the estuary of the Somass River.

Taxa/Station	16	10	5	4	11
Amphipoda	5595.9	14428.7	2985.2	2424.8	
Isopoda	148.3	2796.8	459.1	831	65.9
Tanaidacea		14.1			
Calanoida	28.3				
Cyclopoida	14.1		61.2		37.7
Harpacticoida	3538.3	6467	1228.9	5497	1779.8
Arachnida	91.8	826.3	21.2	21.2	216.6
Ostracoda	558	207.2	9.4		
Insecta	875.8	1090	143.6	527.4	131.8
Oligochaeta	5949	15160.8	8419.9	18602.7	11152.8
Polychaeta	459.1	614.5	131.8	54.2	9.4
Nematoda	8024.9	14522.9	3103.4	8018.3	5781.9
Gastropoda		109			
Foraminifera	84512.3	34959.4	101.3	233.1	3521.8
Total	109,795.8	91,196.7	16,665.0	36,209.7	22,697.7
Number of taxa	26	23	20	17	8

Table 2. Mean number of organisms (m^{-2}) at five sampling sites in the estuary of the Somass River, listed according to the tidal zone sampled: Table 2a. Upper intertidal zone; Table 2b. Mid intertidal zone; Table 2c. Lower intertidal zone; Table 2d. Subtidal zone. Numbers in brackets indicate the number of taxa that were identified and included in a particular larger taxonomic group.

Table 2a. Upper intertidal zone

Taxa/Station	16	10	5	4	11
Amphipoda	56.5		28.3		
Harpacticoida	113	113			395.5
Arachnida	254.3	367.3	56.5	56.5	480.3
Ostracoda	1243	113			
Insecta	2288.4(8)	1412.7(6)	254.4(1)	56.5(3)	395.5(2)
Oligochaeta	4124.5	3757.3	4011.5	141.3	23814.8
Nematoda	5311	3842	56.5	113	8870.5
Gastropoda		395.5			
Foraminifera	63251.8	139837.5			10283
Total	76,642.5	149,838.3	4407.2	367.3	44239.6
Number of Taxa	15	12	7	4	7

Table 2b. Mid intertidal zone

Taxa/Station	16	10	5	4	11
Amphipoda	1808(3)	4011.6(5)	875.9(5)	1723.3(4)	
Isopoda		10989.3	1638.5	1384.3	169.5
Tanaidacea		56.5			
Cyclopoida			84.8		
Harpacticoida	6921.3	8560	2429.5	17430.3	4181
Arachnida	56.5	2938		28.3	169.5
Ostracoda	875.8				
Insecta		762.8(3)	28.3	593.3	
Oligochaeta	4633	36809.8	10226.5	48392.3	7655.8
Polychaeta		254.3		56.5	28.3
Nematoda	4887.3	8559.8	397.8	18390.8	6751.8
Gastropoda		28.3			
Foraminifera	245097		141.3		226
Total	264278.9	72970.4	15822.6	87999.1	19181.9
Number of Taxa	9	16	12	11	7

Table 2c Lower intertidal zone

Taxa/Station	16	10	5	4	11
Amphipoda	17882.4(6)	40595.3(7)	7571.2(6)	5452.3(5)	
Isopoda	480.3	197.8	197.8	1073.5	28.3
Calanoida	113				
Cyclopoida	56.5		84.8		113
Harpacticoid	4407	14068.5	1921	3164	762.8
Arachnida	56.5		28.3		
Ostracoda	113	339			
Insecta	988.8(2)	1469 (2)	254.3	593.3	
Oligochaeta	5734.8	13786	5960.8	10396.3	1987.8
Polychatea	706.3	847.5	452	84.8	
Nematoda	15763.5	39889	8079.9	11497.8	1723.3
Foraminifera	29210.5			932.3	56.5
Total	75512.6	111192.1	24550.1	33194.3	4671.7
Number of Taxa	19	15	16	12	6

Table 2d: Subtidal zone

Taxa/Station	16	10	5	4	11
Amphipoda	2636.7(5)	13108 (4)	3465.4(5)	2523.7(4)	ns*
Isopoda	113			866.3	ns
Tanaidacea				37.7	ns
Cyclopoida			75.3		ns
Harpacticoida	2712	3126.3	565	1393.7	ns
Ostracoda		376.7	37.7		ns
Insecta	226 (2)	715.6(2)	37.3(1)	866.4(2)	ns
Oligochaeta	9303.7	6290.3	13480.8	15481	ns
Polychaeta	1130 (2)	1356	75.3	75.3	ns
Nematoda	6137.7	5800.7	3879.7	2071.7	ns
Foraminifera	489.7		263.7		ns
Total	22748.8	30773.6	21880.2	23315.8	
Number of Taxa	14	11	13	12	

* ns - not sampled

Table 3. Stomach contents (mean number of prey items per fish) of nine species of fish captured in the intertidal zone of the Somass River estuary. Numbers in brackets indicate the number of taxa within a particular larger taxonomic group. Table 3a. Chinook salmon (Oncorhynchus tshawytscha); Table 3b. Chum salmon (O. keta); Table 3c. Sockeye salmon (O. nerka); Table 3d. Coho salmon (O. kisutch); Table 3e. Rainbow trout (Salmo gairdneri); Table 3f. Pacific staghorn sculpin (Leptocottus armatus); Table 3g. Starry flounder (Platichthys stellatus); Table 3h. Threespine stickleback (Gasterosteus aculeatus); Table 3i. Shiner perch (Cymatogaster aggregata).

Table 3a. Chinook salmon (Oncorhynchus tshawytscha)

Taxa/Station	16	10	5	4	11
Amphipoda	2.61(6)	4.09(4)	2.61(6)	2.10(6)	0.02(2)
Isopoda	0.13(1)	0.04(1)	0.43(1)	0.04(1)	0.28(1)
Mysidacea	0.01(1)	0.06(1)	0.12(1)	0.03(1)	
Arachnida	0.01(1)		0.02(1)	0.01(1)	
Insecta	1.63(10)	1.43(10)	3.10(10)	4.42(10)	2.52(12)
Oligochaeta	0.01(1)			0.25(1)	4.62(1)
Polychaeta		0.05(1)	0.01(1)	0.03(2)	
Nematoda					0.02(1)
Fish	0.01(1)				
Total	4.41	5.67	6.29	6.88	7.46
Number of taxa	21	17	20	22	17
Number of stomachs	88	82	83	73	82
Number of empty stomachs	16	6	7	12	7

Table 3b. Chum salmon (Oncorhynchus keta)

Taxa/Station	16	10	5	4	11
Amphipoda	0.42(4)	1.77(2)	6.30(3)	1.14(1)	0.14(1)
Isopoda			0.08(1)		
Tanaidaceae				0.14(1)	
Mysidaceae	0.05(1)			0.14(1)	
Harpacticoida		0.22(1)	12.23(1)		
Arachnida					0.14(1)
Insecta	2.42(7)	3.22(5)	1.54(5)	1.71(4)	1.14(5)
Oligochaeta	0.05(1)			7.86(1)	
Polychaeta	0.05(1)				
Total	2.99	5.21	20.15	10.99	1.42
Number of taxa	14	8	10	8	7
Number of stomachs	19	9	13	7	7
Number of empty stomachs	1	1	4	0	0

Table 3c. Sockeye salmon (Orcorhynchus nerka)

Taxa/Station	16	10	5	4	11
Amphipoda	0.53(5)	0.53(1)		0.04(1)	
Mysidaceae	0.06(1)	0.05(1)		0.04(1)	
Harpacticoida		0.58(1)			
Insecta	1.0 (5)	0.42(5)	0.5(3)	1.5 (4)	
Oligochaeta				0.45(1)	
Total	1.59	1.58	0.5	2.03	0
Number of taxa	11	8	3	7	0
Number of stomachs	15	19	24	22	5
Number of empty stomachs	3	10	9	1	5*

* all five stomachs contained a small amount of unidentifiable digested food.

Table 3d. Coho salmon (Oncorhynchus kisutch)

Taxa/Station	16	10	5	4	11
Amphipoda		29.6(5)	18.4(3)	2.33(3)	
Isopoda		1.8(1)	4.0(1)		
Insecta	8(3)	0.4(2)	2.8(1)	0.66(2)	
Polychaeta				0.33(1)	
Fish			0.2(1)		
Total	8	31.8	25.4	3.32	0
Number of taxa	3	8	6	6	0
Number of stomachs	1	5	5	3	0
Number of empty stomachs	0	0	0	0	0

Table 3e. Rainbow trout (Salmo gairdneri)

Taxa/Station	16	10	5	4	11
Amphipoda	2.5(3)	1.31(2)	1 (3)	8 (1)	
Isopoda		0.06(1)	0.33(1)		
Harpacticoida	4.5(1)	2.75(1)		0.5(1)	
Insecta		0.5 (4)			
Nematoda			0.66(1)		
Fish					
Total	7	4.62	1.99	8.5	0
Number of taxa	4	8	5	2	0
Number of stomachs	4	16	3	2	0
Number of empty stomachs	0	4	2	0	0

Table 3f. Pacific staghorn sculpin (Leptocottus armatus)

Taxa/Station	16	10	5	4	11
Amphipoda	3.05(5)	8 (6)	5.56(5)	1.3 (3)	0.13(2)
Isopoda	2.05(1)	0.07(1)	3.26(1)	0.23(1)	1.4 (1)
Mysidaceae		0.43(1)	0.04(1)		0.01(1)
Calanoida					1.62(1)
Ostracoda			0.13(1)		
Insecta	0.16(2)			0.31(3)	3.37(6)
Oligochaeta					0.72(1)
Nematoda			0.04(1)		0.15(1)
Gastropoda					0.73(1)
Eggs	2.44(1)		0.22(1)		0.06(1)
Total	7.7	8.5	9.25	1.84	8.19
Number of taxa	9	8	10	7	15
Number of stomachs	18	14	23	13	68
Number of empty stomachs	0	0	3	0	7

Table 3g. Starry flounder (*Platichthys stellatus*)

Taxa/Station	16	10	5	4	11
Amphipoda	8.5(1)	5.66(2)		12.87(2)	
Isopoda	10. (2)	2.33(1)		9.12(1)	0.12(1)
Mysidaceae		0.16(1)		0.12(1)	
Calanoida					1.0 (1)
Arachnida					0.06(1)
Insecta				4.5 (1)	0.69(2)
Oligochaeta					3.94(1)
Total	18.5	8.15	0	26.61	5.81
Number of taxa	3	4	0	6	6
Number of stomachs	2	6	1	8	16
Number of empty stomachs	0	0	1	2	0

Table 3h. Threespine stickleback (*Gasterosteus aculeatus*)

Taxa/Station	16	10	5	4	11
Amphipoda	1.22(5)	1.54(6)	0.28(2)	0.13(2)	0.06(1)
Isopoda					0.02(1)
Tanaidaceae					0.06(1)
Mysidaceae		1.56(2)	0.07(1)	0.02(1)	0.82(2)
Calanoida	5.06(1)	0.98(1)			
Harpacticoida	0.09(1)	0.07(1)		0.05(1)	0.56(1)
Arachnida					0.02(1)
Ostracoda		0.02(1)			
Insecta	0.09(1)	2.88(5)	7.64(3)	16.66(4)	3.82(4)
Oligochaeta		0.03(1)		2.31(1)	0.36(1)
Polychaeta		0.17(1)		0.05(1)	
Nematoda		0.03(1)	0.14(1)	0.51(1)	0.68(1)
Gastropoda			1.0 (1)		
Eggs	0.06(1)	0.53(1)	1.43(1)	0.13(1)	0.04(1)
Total	6.52	7.81	10.56	19.86	6.44
Number of taxa	9	20	9	12	14
Number of stomachs	32	57	14	39	50
Number of empty stomachs	4	3	2	2	9

Table 3i. Shiner perch (Cymatogaster aggregata)

Taxa/Station	16	10	5	4	11
Amphipoda	0.08(1)	0.16(1)		0.16(2)	
Isopoda	2.25(1)	0.21(1)		0.05(1)	
Mysidaceae		0.21(1)			
Insecta				18.79(3)	
Polychaeta		0.05(1)		0.05(1)	
Total	2.33	0.63	0	19.05	0
Number of taxa	2	4	0	7	0
Number of stomachs	12	19	2	19	2
Number of empty stomachs	2	3	2	1	2

Table 4. A summary of the primary and secondary prey categories of juvenile fish captured in the intertidal zone of the Somass River estuary, May to July 1975.

Species (mean length) (mm)	Dietary importance (numerical basis)	Site				
		16	10	5	4	11
Chinook salmon (43.3-63.7)	1°	Amphipods	Amphipods	Insects	Insects	Oligochaetes
	2°	Insects	Insects	Amphipods	Amphipods	Insects
Chum salmon (43.4-58.6)	1°	Insects	Insects	Copepods	Oligochaetes	Insects
	2°	Amphipods	Amphipods	Amphipods	Insects/ Amphipods	Arachnids/ Amphipods
Sockeye salmon (53.0-62.0)	1°	Insects	Copepods	Insects	Insects	*
	2°	Amphipods	Amphipods/ Insects		Oligochaetes	
Coho salmon (53.0-103.5)	1°	Insects	Amphipods	Amphipods	Amphipods	**
	2°		Isopods	Isopods	Insects	
Rainbow trout (36.4-45.6)	1°	Copepods	Copepods	Amphipods	Amphipods	**
	2°	Amphipods	Amphipods	Nematodes	Copepods	

* no stomach contents
** no fish available from this site

Table 4. cont'd

Species (mean length) (mm)	Dietary importance (numerical basis)	Site				
		16	10	5	4	11
Pacific staghorn sculpin (46.2-68.6)	1°	Amphipods	Amphipods	Amphipods	Amphipods	Insects
	2°	Isopods/Eggs	Mysids	Isopods	Insects	Isopods/Copepods
Starry flounder (48.7-117)	1°	Amphipods	Amphipods	*	Amphipods	Oligochaetes
	2°	Isopods	Isopods		Isopods	Copepods
Threespine stickleback (44.0-48.6)	1°	Copepods	Insects	Insects	Insects	Insects
	2°	Amphipods	Mysids/Amphipods	Eggs	Oligochaetes	Mysids
Shiner perch (54.5-114.7)	1°	Isopods	Isopods/Mysids	*	Insects	
	2°	Amphipods	Amphipods		Amphipods	

* no stomach contents
** no fish available from this site

Figure 1. Sampling locations in the estuary of the Somass River, Port Alberni where benthic invertebrates and fish were collected.

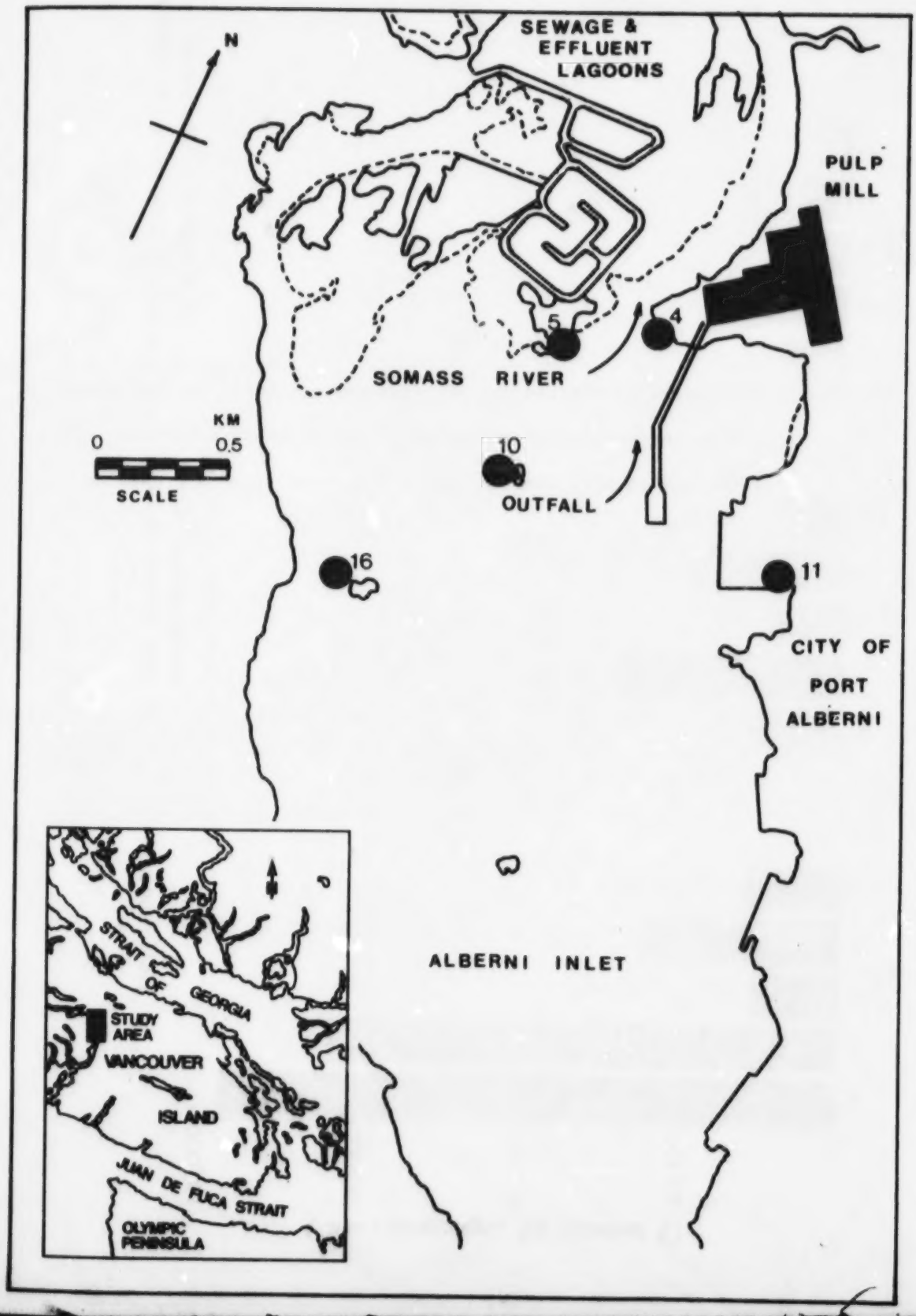

N
SEWAGE &
EFFLUENT
LAGOONS
PULP
MILL
5
4
SOMASS RIVER
KM
0
0.5
SCALE
10
OUTFALL
16
11
CITY OF
PORT
ALBERNI
ALBERNI INLET
STRAIT OF GEORGIA
STUDY
AREA
VANCOUVER
ISLAND
JUAN DE FUCA STRAIT
OLYMPIC
PENINSULA

Figure 2. Histograms of the density of organisms collected at five sites across the estuary of the Somass River. The data for each tidal zone sampled were combined and the mean density is presented.

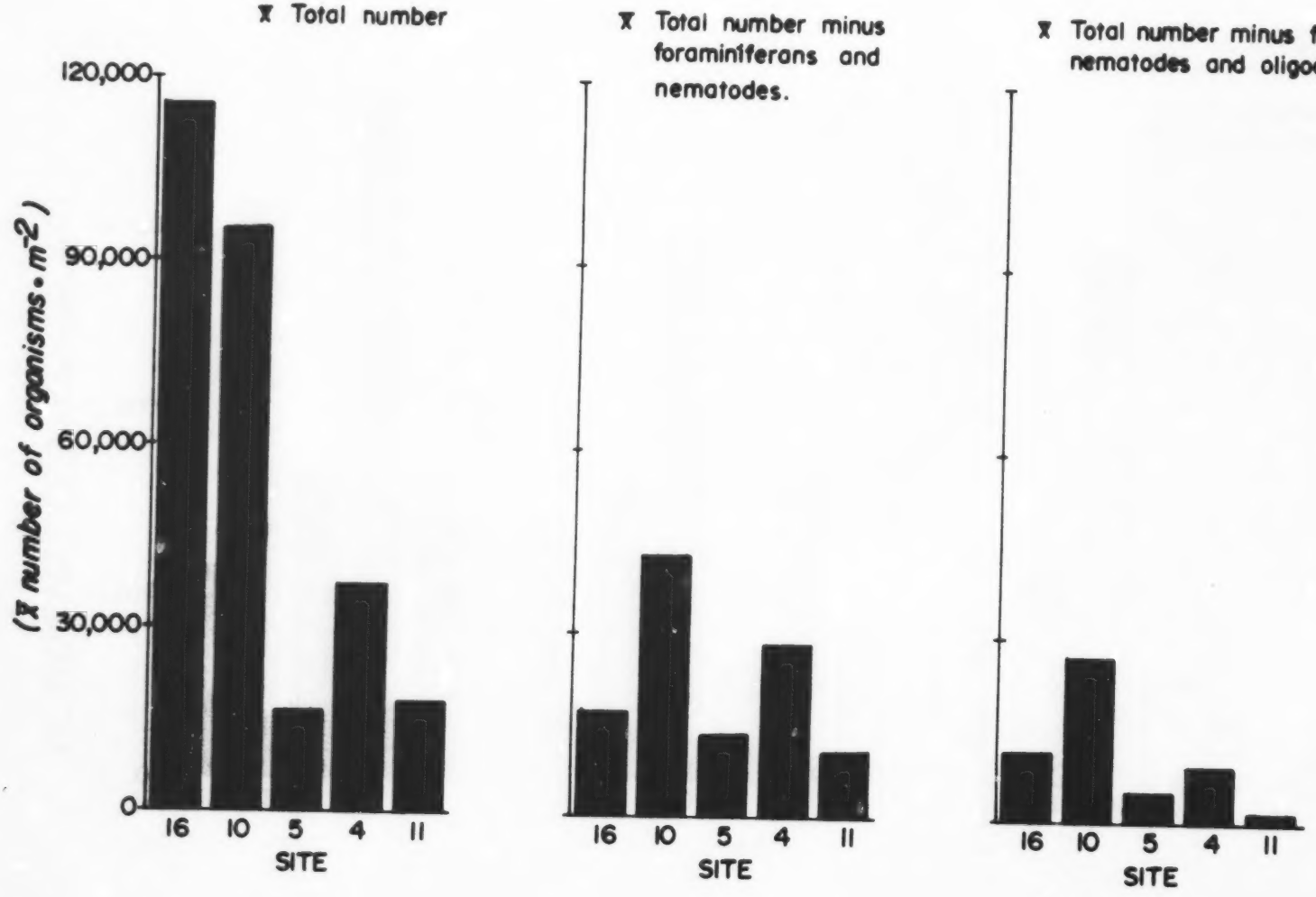

x Total number
120,000
90,000
60,000
30,000
0
(x number of organisms • m-2)
16 10 5 4 11
SITE
x Total number minus foraminiferans and nematodes.
16 10 5 4 11
SITE
x Total number minus foraminiferans, nematodes and oligochaetes.
16 10 5 4 11
SITE

Figure 3. Histograms of the mean density of oligochaetes, nematodes and amphipods at five sites in the estuary of the Somass River.

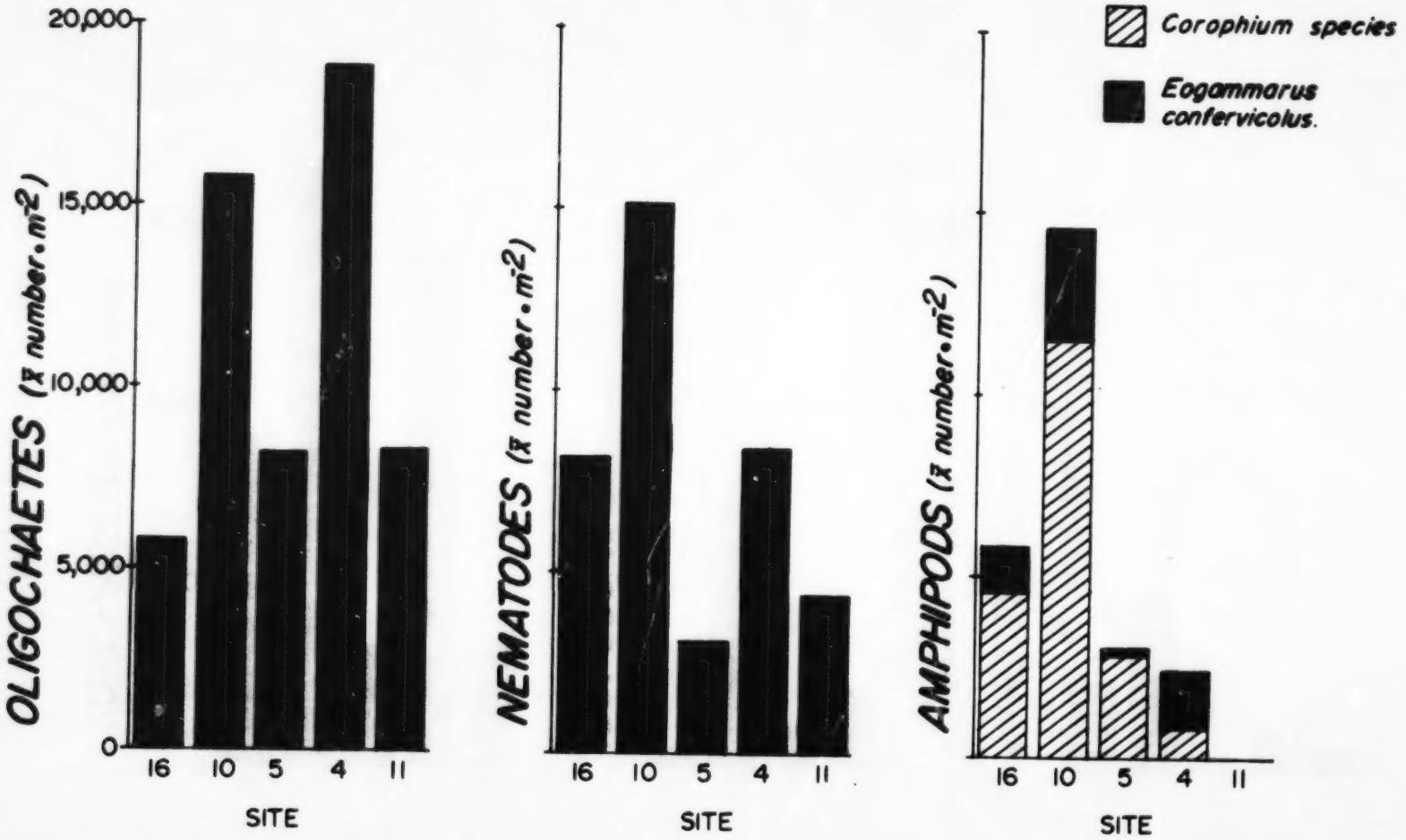

OLIGOCHAETES (x number • m-2)
20,000
15,000
10,000
5,000
0
16 10 5 4 11
SITE
NEMATODES (x number • m-2)
16 10 5 4 11
SITE
AMPHIPODS (x number • m-2)
Corophium species
Eogammarus confervicolus.
16 10 5 4 11
SITE

Figure 4. Histograms of the mean density of copepods, isopods and insects at five sites in the estuary of the Somass River.

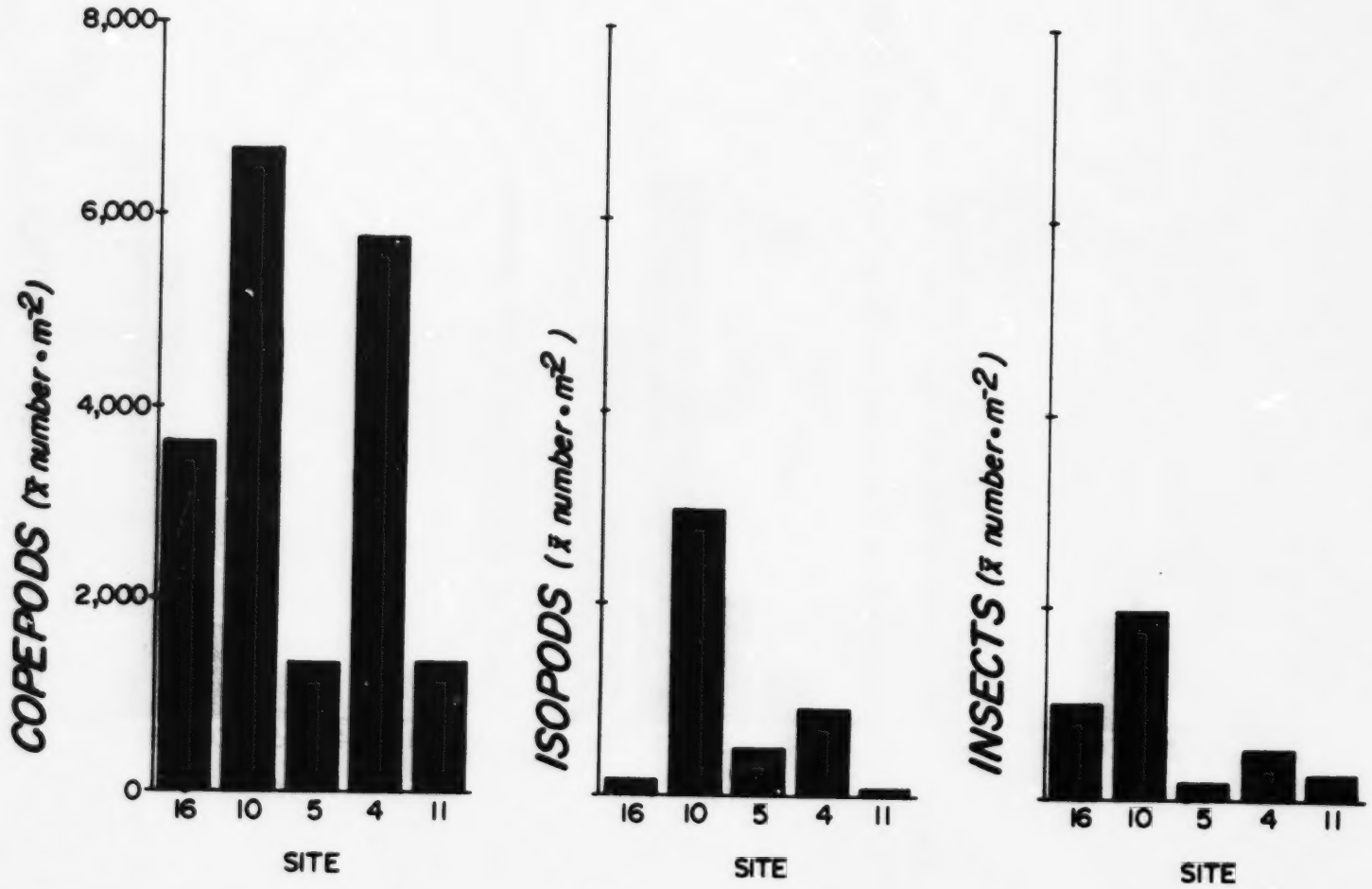

COPEPODS (X number • m-2)
8,000
6,000
4,000
2,000
0
16 10 5 4 11
SITE
ISOPODS (X number • m-2)
16 10 5 4 11
SITE
INSECTS (X number • m-2)
16 10 5 4 11
SITE

Figure 5. Histograms of the mean density of ostracods, polychaetes and gastropods at five sites in the estuary of the Somass River.

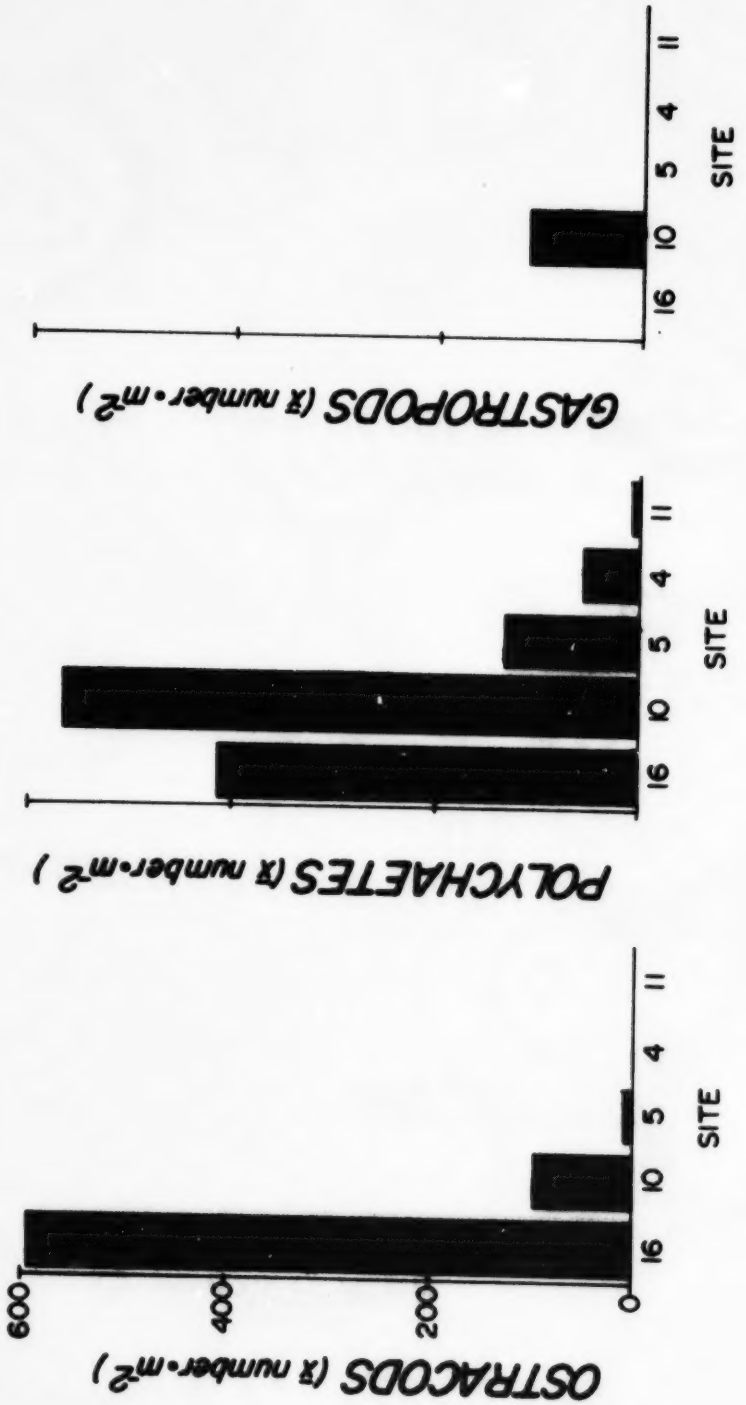

OSTRACODS (x number • m²)
600
400
200
0
16
10
5
4
11
SITE
POLYCHAETES (x number • m²)
16
10
5
4
11
SITE
GASTROPODS (x number • m²)
16
10
5
4
11
SITE

Figure 6. Histograms of the mean density of amphipods at four tidal levels at each of five sites in the estuary of the Somass River.

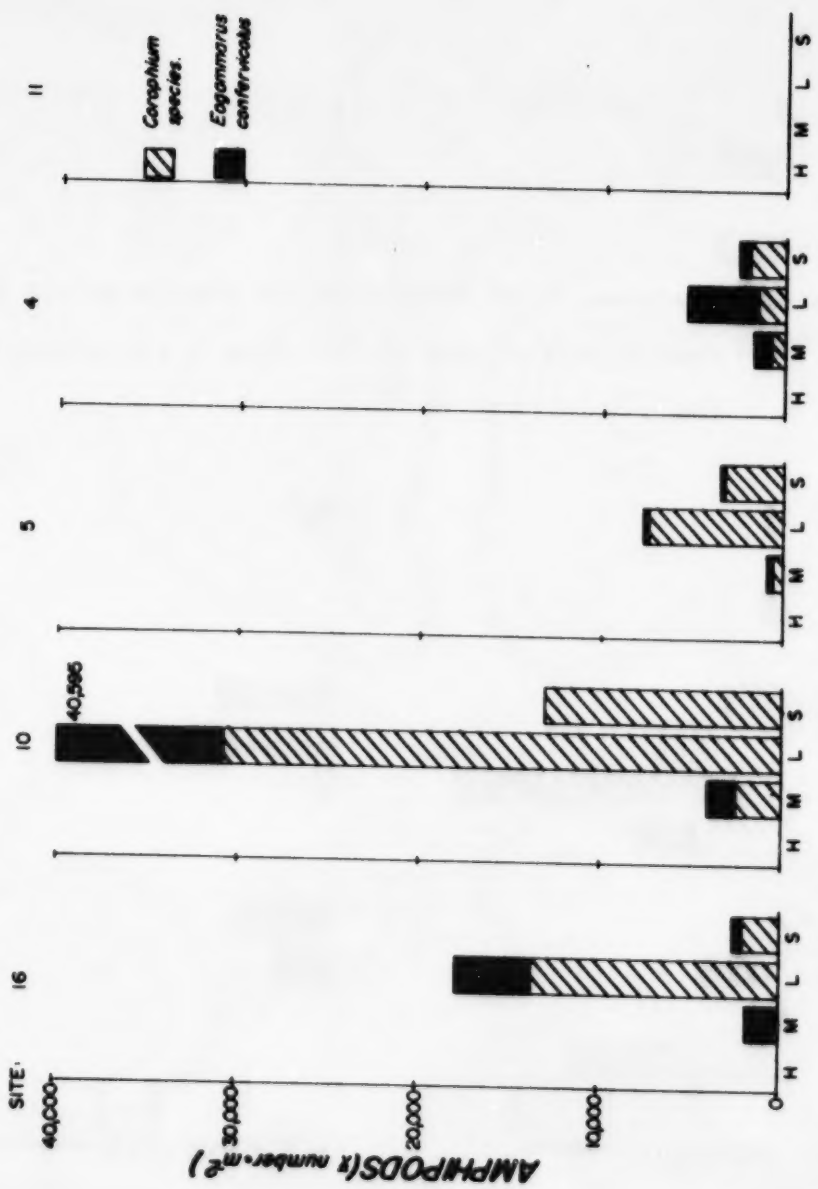

AMPHIPODS (x number·m²)
40,000
30,000
20,000
10,000
0
SITE:
16
10
5
4
11
40,595
H M L S
Corophium species.
Eogammarus confervicolus

Figure 7. Histograms of the mean density of polychaetes and insects at four tidal heights at each of five sites in the estuary of the Somass River.

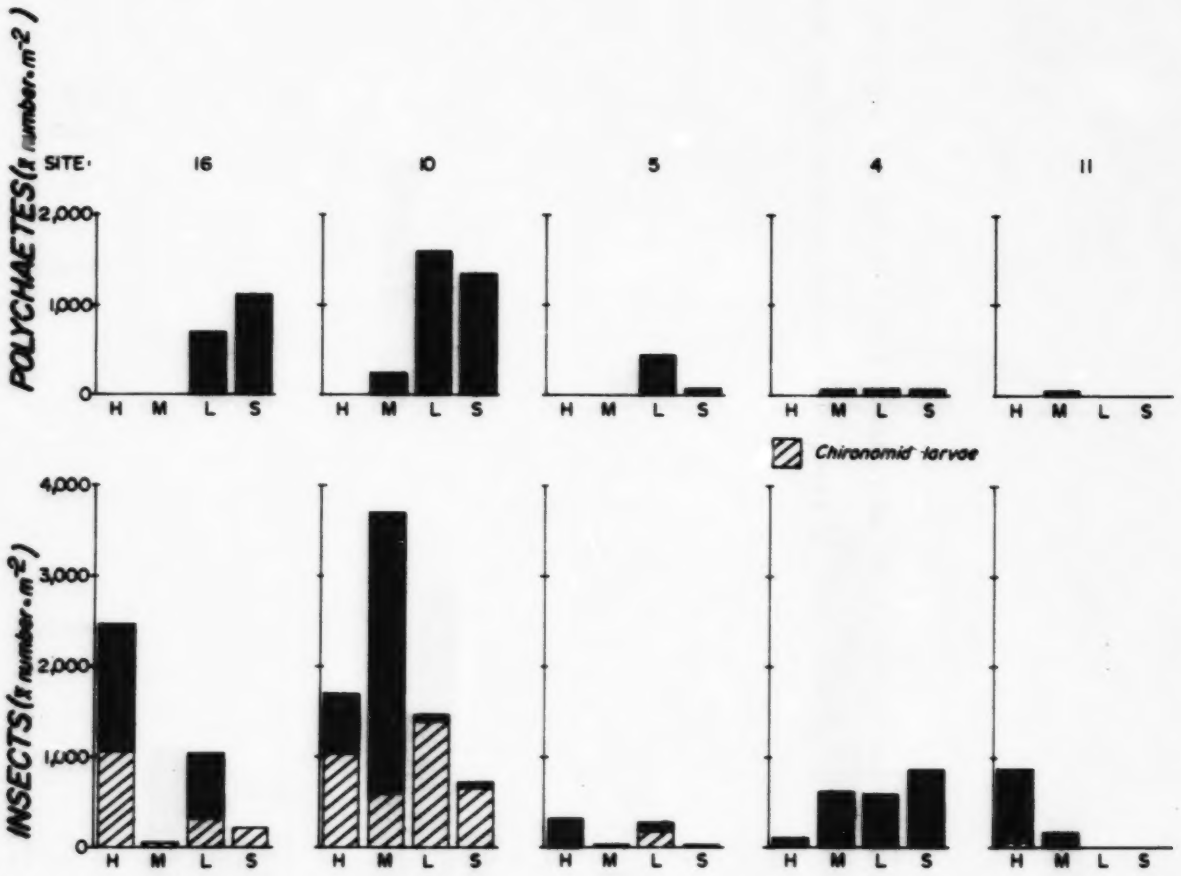

POLYCHAETES (n number.m⁻²)
SITE
16
10
5
4
11
2,000
1,000
0
H M L S
Chironomid larvae
INSECTS (n number.m⁻²)
4,000
3,000
2,000
1,000
0

Figure 8. Histograms of the mean density of isopods and copepods at four tid
heights at each of five sites in the estuary of the Somass River.

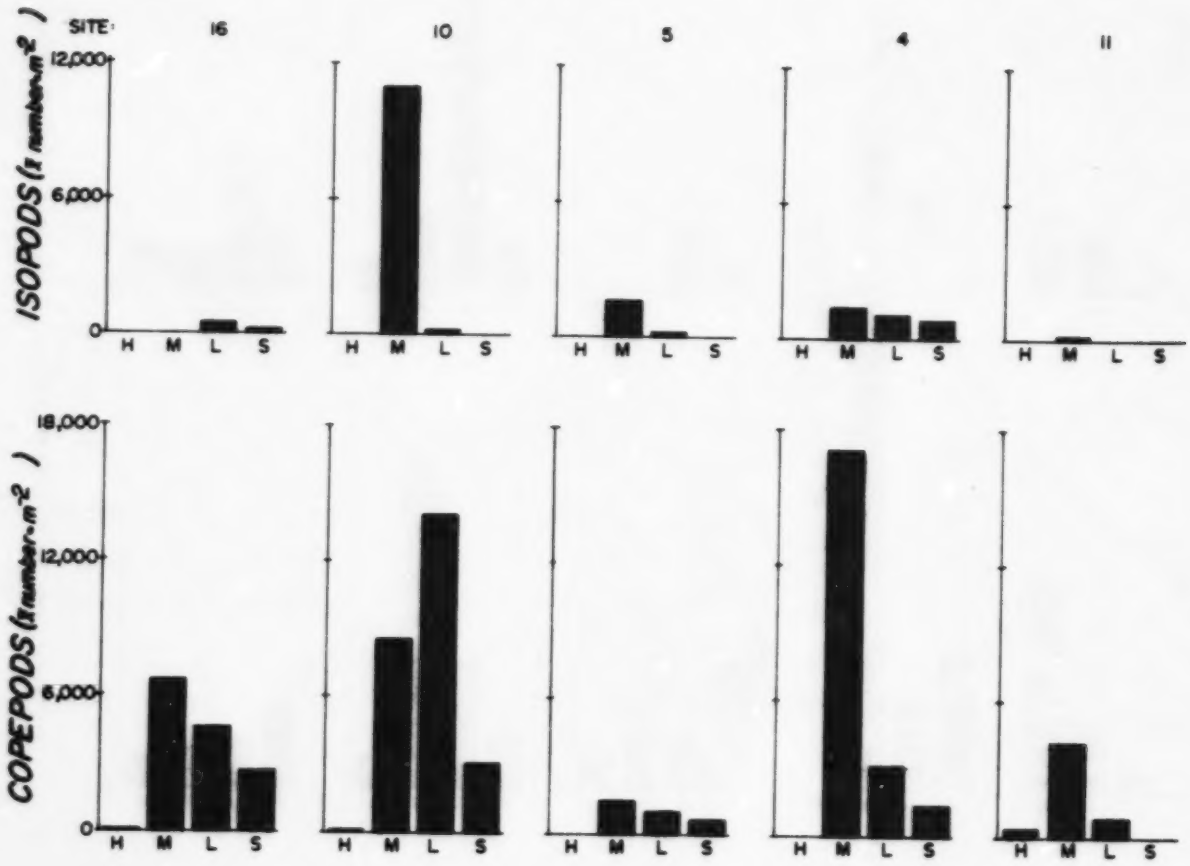

SITE:
16
10
5
4
11
ISOPODS (# number·m⁻²)
12,000
6,000
0
COPEPODS (# number·m⁻²)
18,000
12,000
6,000
0
H M L S

Figure 9. Histograms of the mean density of nematodes and oligochaetes at fo
tidal heights at each of five sites in the estuary of the Somass
River.

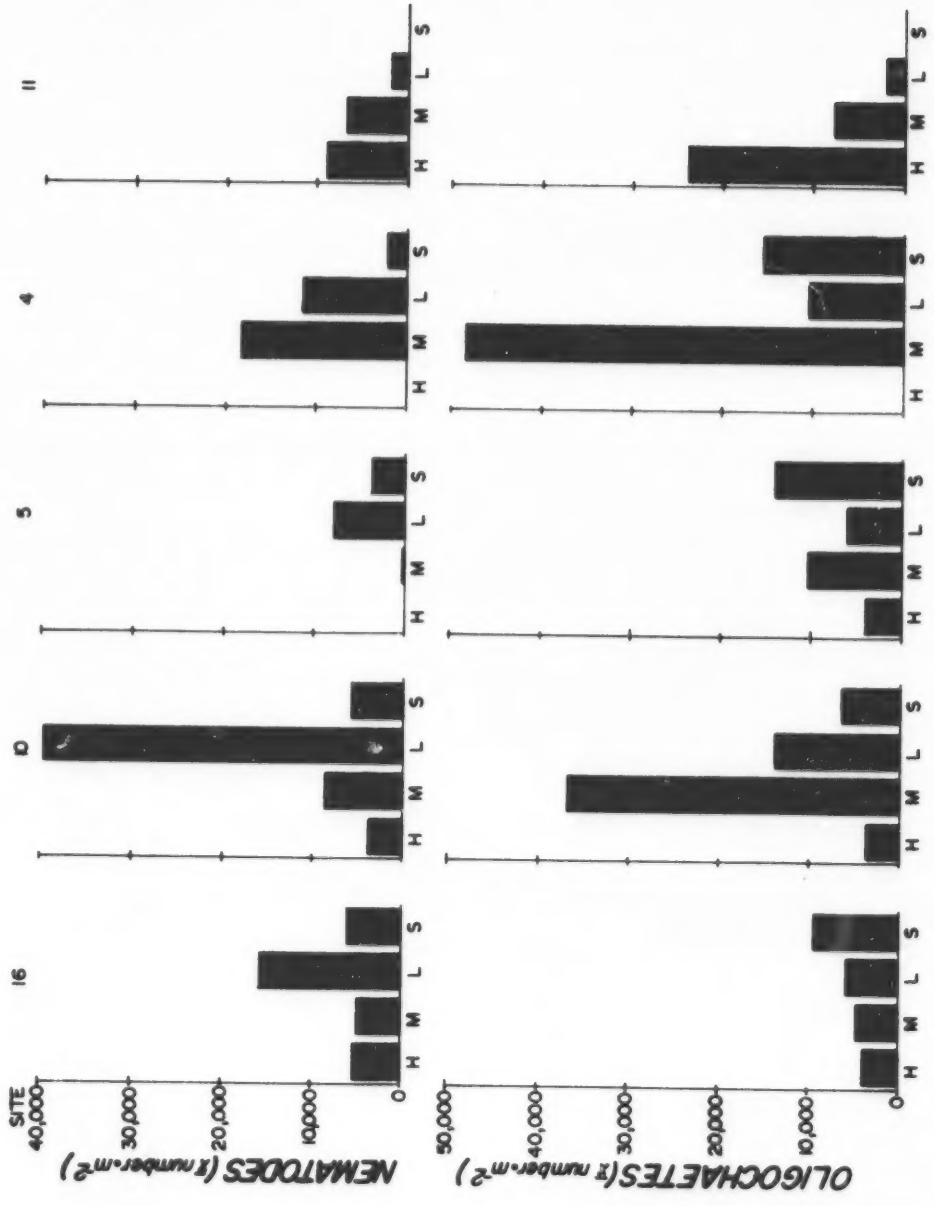

NEMATODES (# number·m²)
OLIGOCHAETES (# number·m²)
SITE
40,000
30,000
20,000
10,000
0
50,000
40,000
30,000
20,000
10,000
0
16
D
5
4
11
H M L S

Figure 10. Histograms of the relative contribution of amphipods, insects, oligochaetes and isopods in the diet of juvenile chinook salmon (Oncorhynchus tshawytscha) collected at five sites in the estuary o the Somass River.

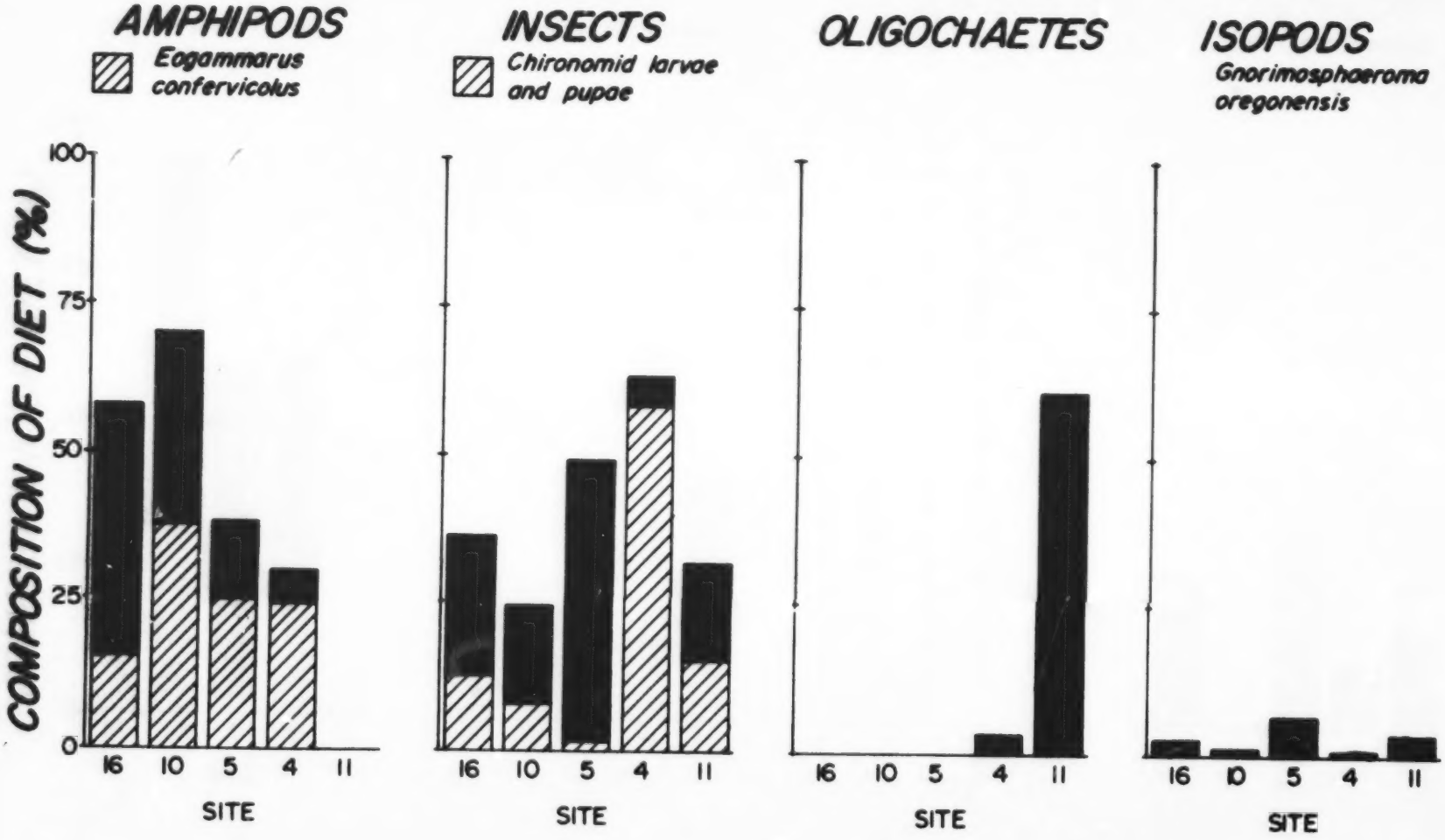

AMPHIPODS
Eogammarus confervicolus
INSECTS
Chironomid larvae and pupae
OLIGOCHAETES
ISOPODS
Gnorimosphaeroma oregonensis
COMPOSITION OF DIET (%)
100
75
50
25
0
16 10 5 4 11
SITE

Figure 11. Histograms of the relative contribution of amphipods, insects, oligochaetes and isopods in the diet of juvenile Pacific staghorn sculpin (Leptocottus armatus) collected at five sites in the estuary of the Somass River.

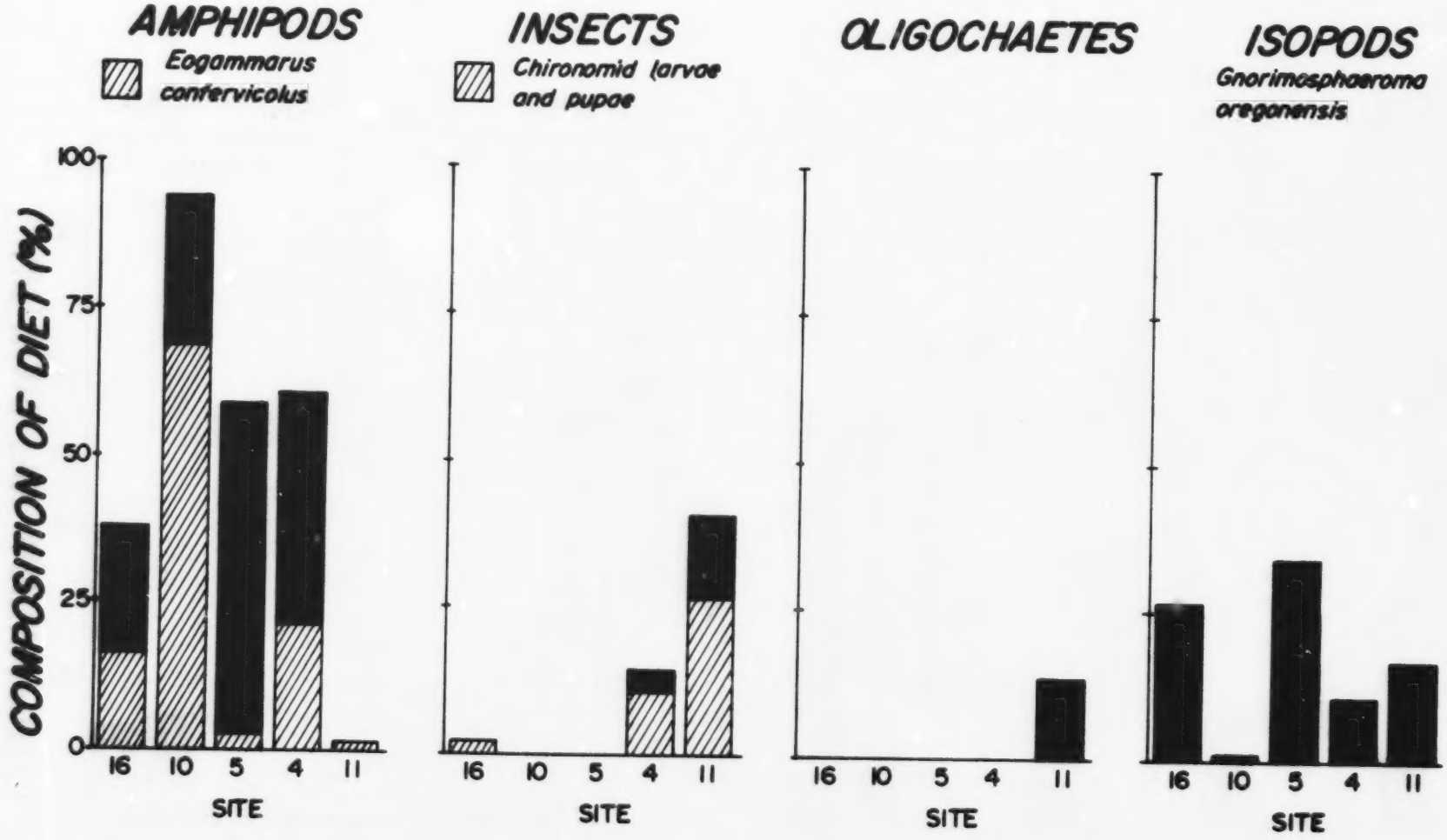
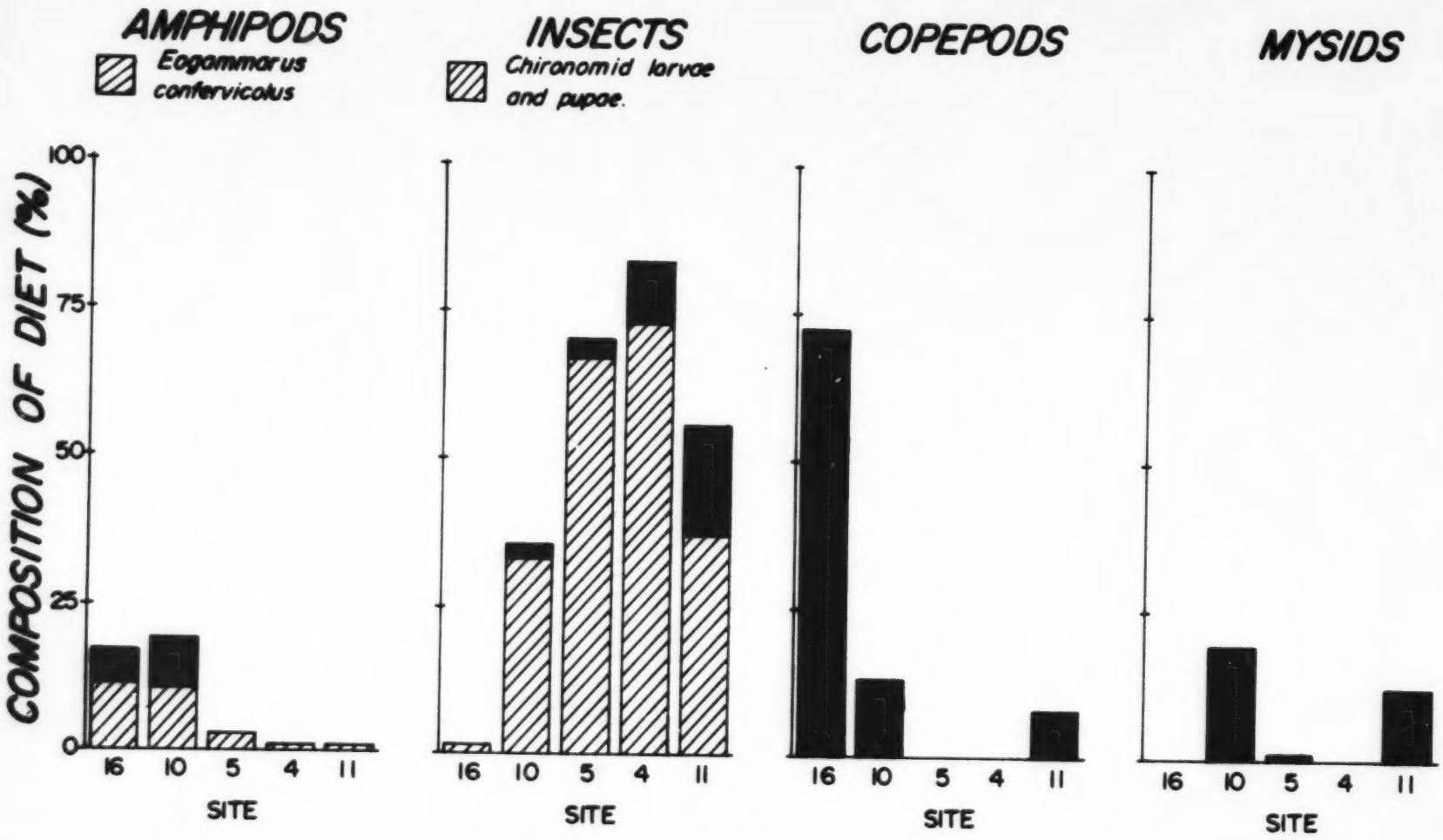

AMPHIPODS
Eogammarus confervicolus
INSECTS
Chironomid larvae and pupae
OLIGOCHAETES
ISOPODS
Gnorimosphaeroma oregonensis
COMPOSITION OF DIET (%)
100
75
50
25
0
16 10 5 4 11
SITE

Figure 12. Histograms of the relative contribution of amphipods, insects, copepods and mysids in the diet of threespine stickleback (Gasterosteus aculeatus) collected at five sites in the estuary of the Somass River.


AMPHIPODS
Eogammarus confervicolus
INSECTS
Chironomid larvae and pupae.
COPEPODS
MYSIDS
COMPOSITION OF DIET (%)
100
75
50
25
0
16 10 5 4 11
SITE